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Geologic Maps for Civil Engineering and Infrastructure Planning

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Geologic Mapping Context: Living off the Land

Artemis Program	The mandate for sustainable, long-term presence on the Moon requires learning to ***"Live off the Land"***. Geologic maps enable a **paradigm shift**: modeling development & scaling of infrastructure for robotic and human exploration inside a bounded system.
Lunar Resources & ISRU	• Geologic Maps: Regolith mineralogy, icy deposits. Plus: residual waste materials. • In-situ resource utilization to produce infrastructure, building materials, consumables.
Science & Geology Mapping	Existing Maps: Coverage of geology, mineralogy, ice/H20, light/shadow, temperature. Future Maps: Details & layers → enable calculation & modeling → resource estimation, modeling trades & infrastructure design → toward a **circular economy**
ISRU Value Chain	Linkages of producers, processes and equipment capabilities for transforming excavated regolith into usable feedstocks. Must be balanced to meet supply and demand across whole system of lunar infrastructure and operations, at each stage of development.

New Lexicon & Taxonomy

Maps:

- Nominally Available:
  - Geology, Mineralogy, H_2O (ice, chemically bonded), Light/Shadow Exposure
  - Terrain, Temperature Ranges/Environmental Data, Highland/Mare
  - Candidate Sites, Prior Landing Sites, Detail Maps
- Needed:
  - Planned Areas for Exploration, Science Stations & Traverse Routes
  - Operational Maps: Progress Indicators, distance traveled/to travel
  - Rover-Based site surveys, Geotechnical Characteristics
  - Nominal Lunar Base Master Plan

Layers:

- Calculated Layers: Power Generation Potential, Maximum Traverse & Transport Distances.
- Overlap & Optimization: Availability & extractability, Calculations of utilization potential.
- Unsituated Elements & Data: Component models & specs to be nested within maps & site plans. Projections of range, setbacks & distances around a given site, path or object.

Catalogs:

- Systems & Equipment - capabilities, operating parameters, dependencies
- Processes - inputs, outputs, operating parameters
- Possible Materials Formulations & Manufactured Components - linked to locations & processes, linked to feedstock precursors & output materials

Constraints:

- Parameters & Specifications
- Hierarchy of goals & functional requirements
- Nominal infrastructure & consumables requirements – areas, volumes, weights, constituent materials & energy/water demand

Temporal Dimension: Mission Timelines, Equipment Payload Deliveries, Operations Timing, Feedstock Accrual, Construction schedules.

4D BIM Models & Whole Systems Overview: Total equipment, infrastructure, feedstock & reserve inventory, plus anticipated/proximal production & deliveries. Evolvable model with interface supporting multiple contributors.

Guiding Questions:

How to Make Geologic Maps Blossom into Infrastructure Plans

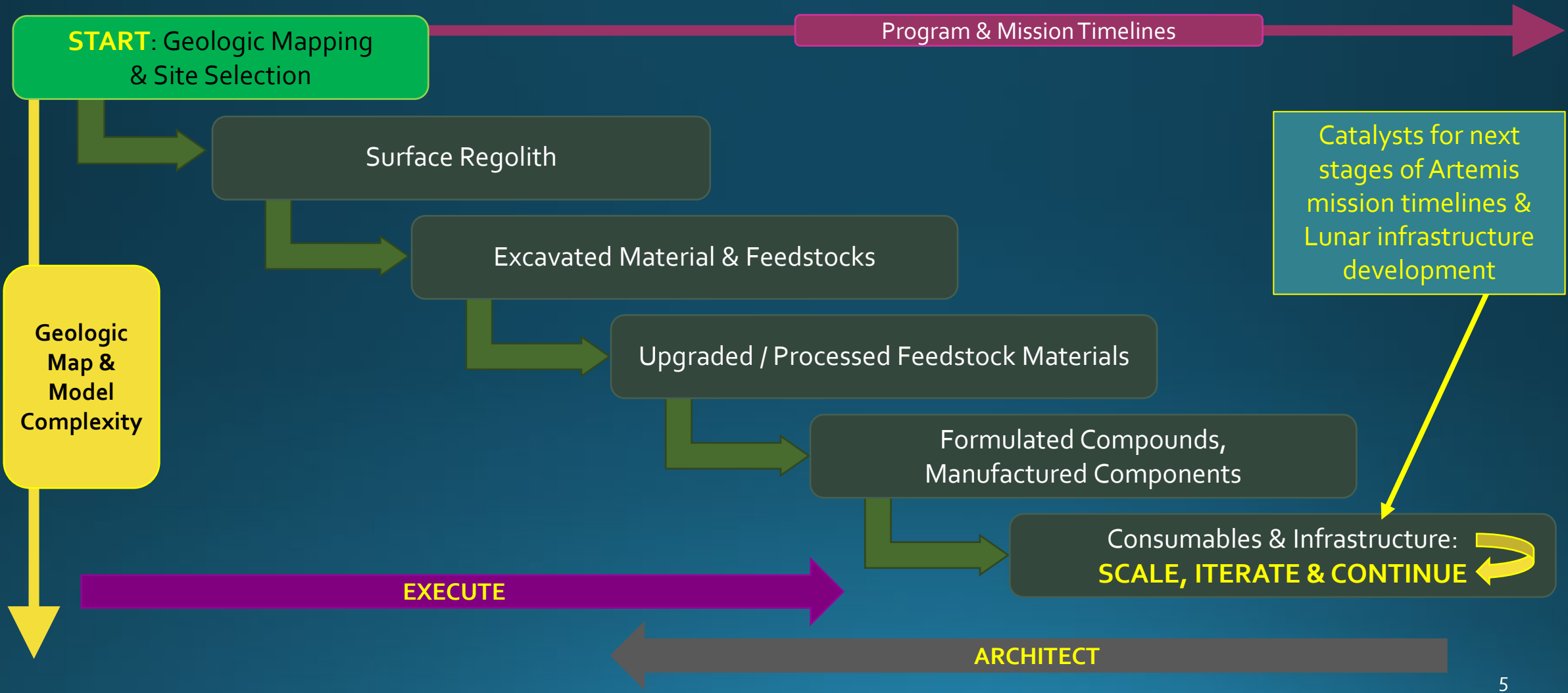
How will we…..

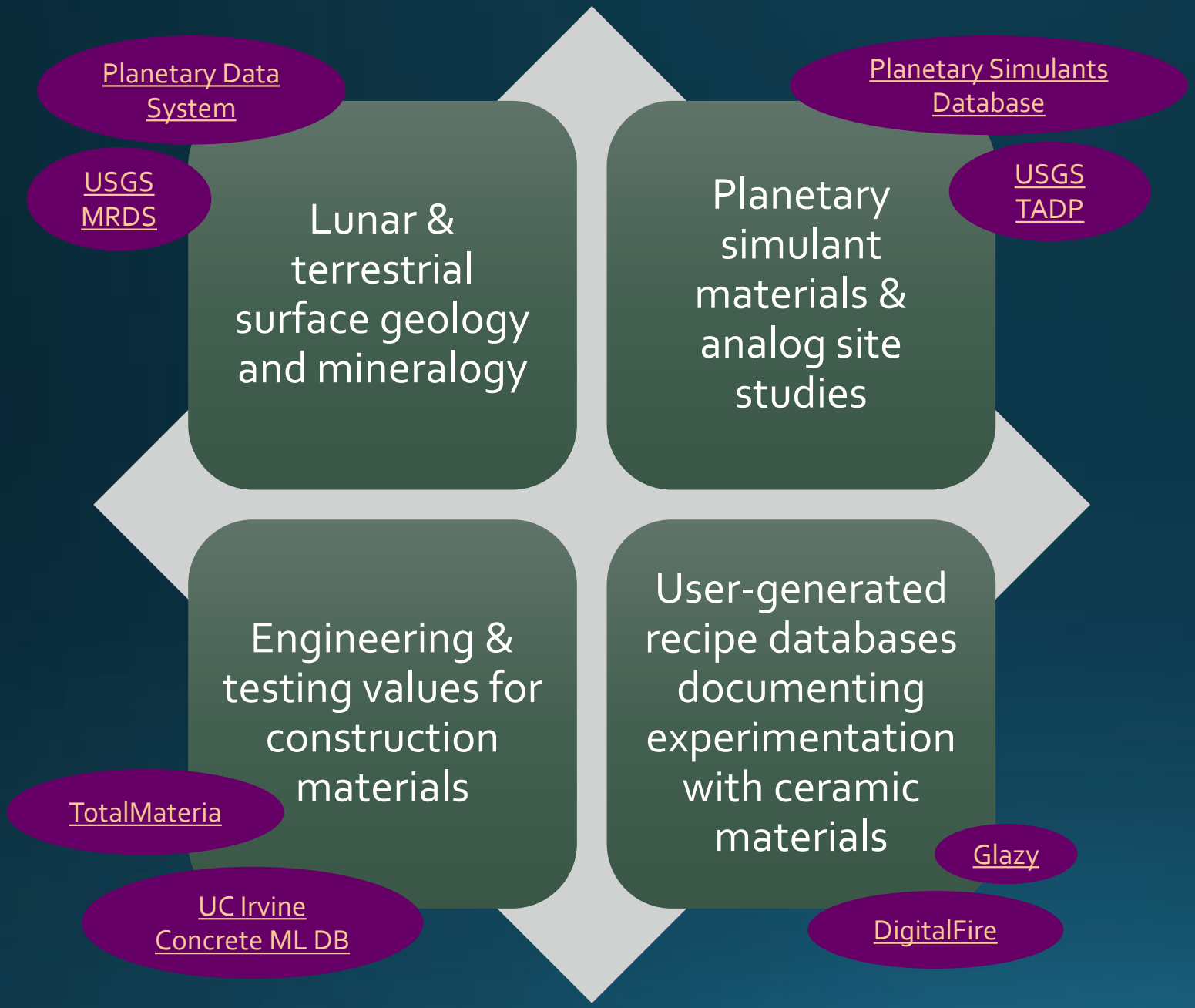
- Track materials and assets to inventory available resources? (Including: power, water, systems)
- Model trades in sites, materials selection, processes, systems, and the consequences for how long-term lunar presence is architected?
- Exchange map & model information among stakeholders?
- Validate performance of materials and components in-situ on the Moon?
- Implement a circular, self-sufficient economy on the Moon?
- Generalize from designing for Earth or the Moon to building with unknown materials, in new planetary environments?

What are the….

- Best examples of data models for lunar materials & construction feedstocks?
- Models that advance geologic mapping & sampling of surface regolith toward manufacturing & building in-situ?

Material Model Building Blocks: from Geology to Civil Infrastructure





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Current Materials Data Tools

Database categories offering models of desirable capabilities

Database Content

Database or Tool Name:	Material Types	Material Formulations	Mineralogy	Geochemistry	Chemistry	Material Mining & Mfg Data	Engineering Values	Procurement Info	Individual Instances
Glazy	Ceramics - Clays & Glazes	x		x	x	x			x
DigitalFire	Ceramics - Clays & Glazes	x		x	x				x
Planetary Simulants Database	Regolith Simulants		x	x	x	x		x	x
USGS Mining Data	Raw Mineral Resources		x	x	x	x		x	
USGS Terrestrial Analogs Data Portal	Field Science Data & Descriptions		x	x		x		x	
TotalMateria	Metal Alloys, Plastics, Composites			x	x		x	x	x
UC Irvine Concrete ML	Concrete & Geopolymers	x		x			x		x

Figure 1 *– Content of Materials Databases.*

Database or Tool Name:	User Accounts	Serialized Batch IDs	Geolocated Records	Multiple Test Types	Multiple Specimen Types	Data Entry via Form	Data Entry via Upload	Data Synth via API	Data Export
Glazy	x	x				x	x		x
DigitalFire	x	x		x	x	x	x		x
Planetary Simulants		x			x				
USGS Mining Data		x	x					x	x
USGS Terrestrial Analogs			x						x
TotalMateria	x	x		x	x				x
UC Irvine Concrete ML					x				x

Figure 2 *– Database Functionality Criteria Comparison.*

TAKEAWAY: No single database offers a complete model or covers all relevant topics.

Total Material Awareness

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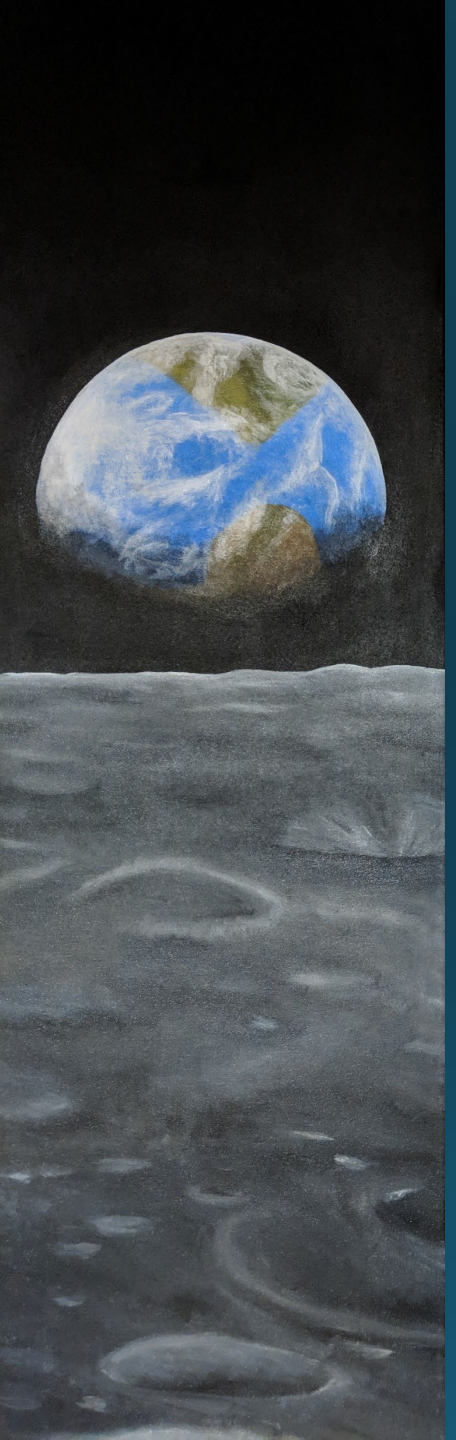
Holistic Geologic Mapping of Lunar Resources

will Require Abilities to: Identify, Know, Track, Search, Suggest, Compare, Substitute

1. Where is it?
2. What is its mineral or chemical composition?
3. What system or entity makes it? How & by what process?
4. How rare or in-demand is it?
5. What can be made from it?
6. What other needs are impacted by its extraction & use?
7. What admixtures, additional inputs or extra-lunar resources does it require?
8. How does it perform? (Specifications? In-situ testing & validation?)
9. Where does it go in its lifecycle? Where / how can it be recovered & reused?
10. How does it handle, feel, look, interact with equipment or other materials?



Recommendations

- **Un-Silo**:
  - Mandate cooperation among NASA Mission Directorates & partner agencies to address critical gaps where expertise overlaps
- **Seek Community Input**:
  - Survey tools used by stakeholders for GIS, CAD, BIM, Modeling, Engineering, Materials Selection & Supply Chain.
  - Experts offer primers for background & common language: standard estimation of terrestrial mineral reserves, geotechnical surveying methods.
- **Define Data Formats & Data Infrastructure:**
  - Define how 3D/4D models, timelines & specs integrate with geological maps.
  - Define metadata requirements for relevant non-spatial information
- **Enable Interoperability & Collaboration:**
  - Define interface for sharing detailed map, model and specification information
  - Who gets to view or edit? At what level of detail, and how soon?
  - Who gets to integrate, calculate, adjust models, optimize?
- **Build Open & Dynamic Supply Chain:**
  - Integrate data on materials, processes & systems from key stakeholders.
  - Model complex trades, offer substitutions, balance systems & optimize production.

Geologic mapping is the bedrock foundation for modeling lunar infrastructure development from regolith-derived resources.

Designing a lunar outpost offers an Earthrise moment for modeling the terrestrial circular economy.

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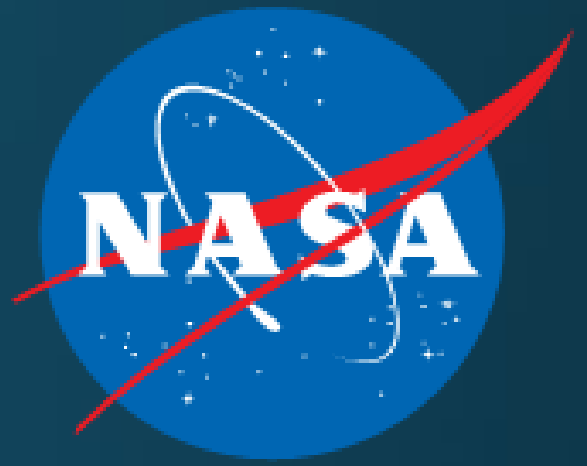
Questions?



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